dc PM motor → K_f constant excitation

$V_a = 110V$, $I_a = 10A$, $R_a = 0.5\Omega$, $N_m = 1200\ rpm$

$P = 2$ pole pairs, $T_e = 2ms$

$= 4$ Poles

$\Delta V = 10V$

Speed response for

$J = 0.005\ Kg\,m^2$, $J = 0.05\ Kg\,m^2$

اعتبر $\Delta T_L = 0$ لانه لم يتم تسليط جهد فجائي ولكنه كان موجود

for constant rated torque امتلك جهد وزاد وبالتالي

لم يوصف stepchange في T_L

$$V_a(s) = R_a I_a(s) + l_a s\, I_a(s) + K_f\, \omega_m(s)$$

$$T_{em} = K_f\, I_a(s)$$

$$= T_L(s) + \omega_m(s)(B + Js)$$

($T_L(s) = 0$)

$$V_a(s) = (R_a + l_a s)\, I_a(s) + K_f\, \omega_m(t)$$

$$V_a(s) = (R_a + l_a s)\,\frac{T_L(s) + \omega_m(s)(B + Js)}{K_f} + K_f\, \omega_m(t)$$

$$\frac{\omega(s)}{V_a(s)} = \frac{K_f}{(R_a + l_a s)(B + Js) + K_f^2}$$

to get K_f

$$V_a = R_a I_a + K_f \omega_m$$

$$110 = 0.5 * 10 + K_f * 1200 * \frac{2\pi}{60}$$

$$K_f = 0.8356$$

$$\tau_e = \frac{l_a}{R_a} = 2*10^{-3}$$

$$L_a = \tau_e R_a = 2*10^{-3} * 0.5 = 10^{-3}\ H$$

$$\omega(s) = \frac{10}{s} \frac{0.8356}{(0.5+10^{-3}s)(0.005s)+(0.8356)^2}$$

$$= \frac{10}{s} \frac{0.8356}{5*10^{-6}s^2 + 2.5*10^{-3}s + 0.69823}$$

$$= \frac{8.356/(5*10^{-6})}{s[s^2 + 500s + 139646]}$$

$2\xi\omega_n$ ω_n^2

$$= \frac{1671200}{s[s+250-277.75i][s+250+j277.75]}$$

$$\omega_d = \omega_n\sqrt{1-\xi^2} \qquad \phi = \cos^{-1}\xi$$

$$W(s) = \frac{10}{s} \frac{167120}{s^2+500s+139646} = \frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$$

$$s^2+500s+139646 = s^2+2\zeta\omega_n s+\omega_n^2$$

$$\omega_n = 373.69$$

$$2\zeta\omega_n = 500$$

$$\zeta = \frac{500}{2*373.69} = 0.669$$

$$\phi = \cos^{-1}(\zeta) = \cos^{-1}(0.669) = 48.01$$

$$W(s) = \frac{10*1.19674}{s} \frac{139646}{s^2+500s+139646}$$

$$\omega_d = \omega_n\sqrt{1-\zeta^2}$$

$$= 373.69 * \sqrt{1-(0.669)^2}$$

$$= 277.74973$$

$$\Delta W(t) = \left[1 - \frac{e^{-\zeta \omega_n t}}{\sqrt{1-\zeta^2}} \sin(\omega_d t + \phi)\right]$$

$= ______$

$$= 11.9674\left[1 - \frac{e^{-250t}}{0.7433} \sin(277.75t + 48)\right]$$

$\omega_0 = 125.664$ rad/sec

$\omega(t) = \omega_0 + \Delta\omega(t)$

$\zeta < 1$ underdamped

EX2 Sep DC gen $\omega_m = const$

$R_a = 0.1\,\Omega,\ R_f = 1\,\Omega,\ l_a = 5\,mH,\ l_f = 0.5\,H$

$V_a = 200\,V,\ I_f = 5\,A,\ I_a = 100\,A,\ N_m = 1500\,rpm$

$$\frac{I_a(s)}{V_f(s)} = \frac{K_w}{(R_f + L_f s)(R + L s)}$$

$$V_a = -R_a i_a - L_a \frac{di_a}{dt} + K_w i_f$$

$K_w = \frac{P}{2} L_{af} \omega_m$

$$= R_L i_a + L_L \frac{di_a}{dt}$$

$$V_f = R_f i_f + L_f \frac{di_f}{dt}$$

$$K_w I_f(s) = R I_a + L s I_a$$

$$V_f(s) = R_f I_f(s) + L_f s I_f(s)$$

$$K_w \frac{V_f(s)}{R_f + L_f s} = R I_a(s) + L s I_a(s)$$

$$\frac{I_a(s)}{V_f(s)} = \frac{K_w}{(R_f + L_f s)(R + L s)}$$

$$\frac{V_a(s)}{V_f(s)} = \frac{K_w (R_L + L_L s)}{(R_f + L_f s)(R + L s)}$$

$$200 = -(0.1 * 100) + K_w (5)$$

$$K_w = 42$$

$$R_L = \frac{V_a}{I_a} = \frac{200}{100} = 2\,\Omega$$

$$R = R_L + R_a = 2 + 0.1 = 2.1\,\Omega$$

$$L_L = 0$$

$$V_f = I_f R_f = 5 * 1 = 5V$$

$$\Delta V_f = \frac{20}{100} V_f = \frac{20}{100} * 5 = 1V \quad (\text{step})$$

$$I_a(s) = \frac{1}{s} \frac{42}{(1 + 0.5s)(2.1 + 5*10^{-3}s)}$$

$$= \frac{1}{s} \frac{42}{0.0025s^2 + 1.0555s + 2.1}$$

$$= \frac{1}{s} \frac{16800}{s^2 + 422s + 840} = \frac{1}{s} \frac{16800}{(s+2)(s+420)}$$

$$= \frac{A}{s} + \frac{B}{s+2} + \frac{C}{s+420}$$

$$A = \lim_{s \to 0} \frac{16800}{(s+2)(s+420)} = 20$$

$$B = \lim_{s \to -2} \frac{16800}{s(s+420)} = -20.0957$$

$$C = \lim_{s \to -420} \frac{16800}{s(s+2)} = 0.0957$$

$$\Delta i_a(t) = 20 - 20.0957 e^{-2t} + 0.0957 e^{-420t}$$

$$i_a(t) = I_0 + \Delta i_a(t) = 100 + \Delta i_a(t)$$

$$V_a(t) = R_L i_a(t)$$

$$= 240 - 40.1914 e^{-2t} + 0.1914 e^{-420t}$$

1 $TF = \frac{W(s)}{V_f(s)}$ rated Torque

dc motor linearized moder نفتكر نتعامل مع

$I_{f_0} = 5A$, $R_f = 1\Omega$, $L_f = 0.05 H$

$I_{a_0} = 100A$, $R_a = 0.1\Omega$, $l_a = 5mH$

$V_{a_0} = 210V$

$J = 1 Kgm^2$, $N_m = 1200 rpm$, $B = 0$

$$\frac{W(s)}{V_f(s)} = \frac{M_{af}[(R_a + l_a s)I_{a_0} - M_{af} I_{f_0} W_{m_0}]}{(R_f + l_f s)[(B + Js)(R_a + l_a s) + M_{af}^2 I_{f_0}^2]}$$

$$V_{a_0} = I_{a_0} R_a + M I_{f_0} W_{m_0}$$

$$210 = (100 * 0.1) + M * 5 * \frac{1200 * 2\pi}{60}$$

$$M = 0.31831$$

$$\frac{W(s)}{V_f(s)} = \frac{0.31831[(0.1 + 0.005 S) * 100 - (0.3183 * 5 * \frac{1200*2\pi}{60})]}{(1 + 0.05 S)[S(0.1 + 0.005 S) + (0.31831 * 5)^2]}$$

$$= \frac{0.31831[(10 + 0.5 S) - 199.99]}{(1 + 0.05 S)[0.1 S + 0.005 S^2 + 2.533]}$$

② DC Separately motor no.load

$V_a = 240V$, $R_f = 120\Omega$, $L_f = 0.7H$, $M = 1.1H$
$J = 0.08\ Kgm^2$

$i_f(t)$, $\omega(t)$

V_f 240 → 100

$\Delta V_f = 100 - 240 = -140$

$\Delta V_a = 0$, $\Delta T_L = 0$

$0 =$

$\Delta V_f = R_f \Delta i_f + L_f \frac{d\Delta i_f}{dt}$

$V_f(s) = R_f I_f(s) + L_f s I_f(s)$

$$\frac{I_f(s)}{V_f(s)} = \frac{1}{R_f + L_f s}$$

$$= \frac{-140}{s} \cdot \frac{1}{120 + 0.7s}$$

$$I_{f_0} = \frac{V_{f_0}}{R_f} = \frac{240}{120} = 2\,A$$

$$= \frac{-200}{s(s+171.42857)}$$

$$= \frac{A}{s} + \frac{B}{s+171.43}$$

$$A = \lim_{s\to 0} \frac{-200}{s+171.43} = -1.1667$$

$$B = \lim_{s\to -171.43} \frac{-200}{s} = 1.1667$$

$$\Delta i_f(t) = -1.1667 + 1.1667\, e^{-171.43t}$$

OR $i_f(t) = I_{f_0} + \Delta i_f(t) = 0.8333 + 1.1667\, e^{-171.43t}$

field circuit is RL circuit with step response (from circuit 2)

$$x(t) = x_f(1 - e^{-t/\tau}) + x_0 e^{-t/\tau}$$

final ↗ ← initial

$$x(t) = x_f + (x_0 - x_f)\, e^{-t/\tau}$$

2

$$i_f(t) = I_{f_{ss}}(1-e^{-t/\tau}) + I_{f_o} e^{-t/\tau}$$

$$\tau = \frac{L_f}{R_f} = \frac{0.7}{120} = 5.833 * 10^{-3} \text{ sec}$$

$$I_{f_{final}} = \frac{V_{f_f}}{R_f} = \frac{100}{120} = 0.8333 A$$

$$I_{f_{initial}} = \frac{V_{f_o}}{R_f} = \frac{240}{120} = 2 A$$

~~x(t) =~~

$$i_f(t) = I_{f_{s.s}} + (I_{f_o} - I_{f_{s.s}}) e^{-t/\tau}$$

$$= 0.8333 + (-0.8333 + 2) e^{-171.428t}$$

$$= 0.8333 + 1.1667 e^{-171.428t}$$

$$\frac{\omega(s)}{V_f(s)} = \frac{M_{af}[(R_a + l_a s) I_{a_o} - M_{af} I_{f_o} \omega_{m_o}]}{(R_f + l_f s)[(B + Js)(R_a + l_a s) - M_{af}^2 I_{f_o}^2]}$$

no load $I_{a_o} = 0$

خطأ لم تحل بهذه الطريقة

$$= \frac{-(1.1)^2 * 2 * 109.091}{(120+0.75)[0.085}$$

(crossed out)

$$V_a = R_a i_a + L_a \frac{di_a}{dt} + M_{af} i_f \omega_m$$

$$V_f = R_f i_f + L_f \frac{di_f}{dt}$$

$$T_{em} = M_{af} i_a i_f$$

$$= T_L + B\omega_m(t) + J\frac{d\omega_m(t)}{dt}$$

at no load $i_a = 0$

$$V_a = M_{af}\, i_f(t)\, \omega_m(t)$$

$$\omega_m(t) = \frac{V_a}{M\, i_f(t)} = \frac{240}{1.1 * (0.8333 + 1.1667 e^{-171.428t})}$$

$$= \frac{240}{0.91663 + 1.28337 e^{-171.428t}}$$

③ Sep dc gen   1433 rpm

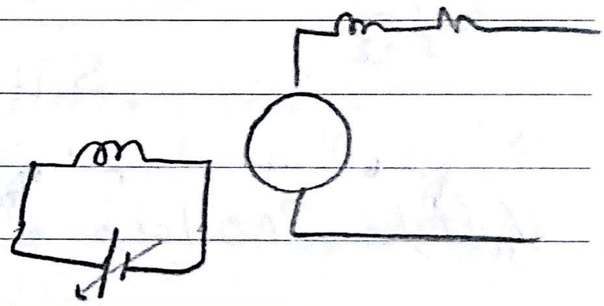
$R_a = 0.1\,\Omega$, $l_a = 0.3\,mH$, $R_f = 80\,\Omega$, $l_f = 40\,H$

$M = 0.8\,H$

ⓐ $V_f = 0$ ~~$V_a = 0$~~ $\rightarrow V_a(t)$

$V_f \rightarrow 0 \rightarrow 160V$

armature open
field excited



$$V_a = -R_a i_a - l_a \frac{di_a}{dt} + K_\omega i_f$$

$$K_\omega = M_f \frac{P}{2} \omega_m$$

$$V_a(s) = K_\omega I_f(s)$$

$$V_f(s) = (R_f + l_f s)\, I_f(s)$$

$$V_a(s) = K_\omega \frac{V_f(s)}{R_f + l_f s}$$

$$\frac{V_a(s)}{V_f(s)} = \frac{K_\omega}{R_f + l_f s} = \frac{0.8 * \frac{1433 * 2\pi}{60}}{80 + 40s}$$

480.2029

$$V_a(s) = \frac{160}{s} \cdot \frac{3.00127}{s+2} = \frac{A}{s} + \frac{B}{s+2}$$

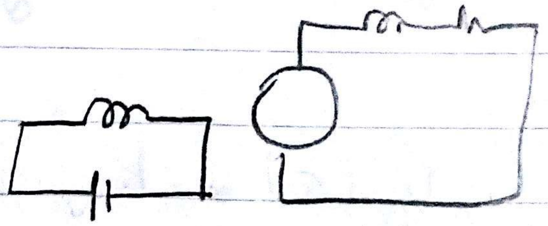
$$A = \lim_{s \to 0} \frac{480.2029}{s+2} = 240.1015$$

$$B = \lim_{s \to -2} \frac{480.2029}{s} = -240.1015$$

$$V_a(t) = 240.1015 - 240.1015\, e^{-2t}$$

6

$\Delta V_p = 160V$
armature → s.c



$$V_a = -R_a i_a - L_a \frac{di_a}{dt} + K_w i_f$$

$$= R_L i_a + L_L \frac{di_a}{dt} = 0$$

$$K_w I_f(s) = R_a I_a(s) + L s I_a(s)$$

$$V_f(s) = (R_f + L_f s) I_f(s)$$

$$K_{\omega}\frac{V_f(s)}{R_f+l_f s}=(R_a+l_a s)I_a(s)$$

$$\frac{I_a(s)}{V_f(s)}=\frac{K_{\omega}}{(R_f+l_f s)(R_a+l_a s)}$$

$$I_a(s)=\frac{160}{s}\cdot\frac{0.8*\frac{1433*2\pi}{60}}{(80+40s)(0.1+0.3*10^{-3}s)}$$

$$=\frac{\frac{160*0.8*1433*2\pi}{60*40*0.3*10^{-3}}}{s(s+2)(s+333.33)}$$ → 1600676.364

$$=\frac{A}{s}+\frac{B}{s+2}+\frac{C}{s+333.33}$$

$$A=\lim_{s\to 0}\frac{1600676.364}{(s+2)(s+333.33)}=2401.039$$

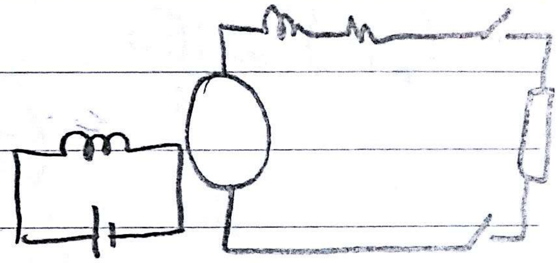
$$B=\lim_{s\to -2}\frac{1600676.364}{s(s+333.33)}=-2415.532$$

$$C=\lim_{s\to -333.33}\frac{1600676.364}{s(s+2)}=14.493$$

$$\Delta i_a(t) = 2401.039 - 2415.532\, e^{-2t} + 14.493\, e^{-333.33t}$$

$$i_a(t) = I_{a_0} + \Delta i_a(t) = \Delta i_a(t)$$

[c] $V_{a_{s.s}}$ of **[a]**



$V_{a_{ss_0}} = 240.1015\,V$

Suddenly $R_l = 1.1\,\Omega$
$L_l = 1.7\,mH$

Step response of R-L circuit

$i_a(t) = ?$, $V_a(t) = ?$

$$i(t) = \frac{V_s}{R} + \left(I_0 - \frac{V_s}{R}\right) e^{-\frac{R}{L}t}$$

$$i(t) = \frac{240.1015}{1.2} + \left(0 - \frac{240.1015}{1.2}\right) e^{-\frac{1.2}{0.002}t}$$

$R = R_a + R_l = 0.1 + 1.1 = 1.2\,\Omega$
$L = L_a + L_l = (0.3 + 1.7) * 10^{-3} = 2\,mH$

$i(t) = 200.0845 - 200.0845 e^{-600t}$

$V_a(t) = R_L i_a(t) + L_L \frac{d i_a(t)}{dt}$

$= 1.1 * (200.0845 - 200.0845 e^{-600t})$

$+ 1.7 * 10^{-3} (-200.0845 * -600 e^{-600t})$

$= 220.09295 - 220.09295 e^{-600t}$

$+ 204.08619 e^{-600t}$

$= 220.09295 - 16.00676 e^{-600t}$

d $T_e(t) = M_{af} I_f I_a(t)$

V_f did not change in this case so I_f don't change

$I_{f_{ss}} = \frac{160}{R_f} = \frac{160}{80} = 2A$

$T_e(t) = 0.8 * 2 * (200.0845 - 200.0845 e^{-600t})$

e)

2nd SoL

$E = 240.102\,V$

$\tau_a = \frac{L_a}{R_a} = \frac{0.3 \times 10^{-3}}{0.1} = 3 \times 10^{-3}\,s$

$i_a(t) = \frac{E}{R_t}(1 - e^{-t/\tau_a}) + I_{a_0} e^{-t/\tau}$

$\frac{E}{R_t} \rightarrow I_{af}$

$= \frac{240.102}{1.6}(1 - e^{-t/\tau_a}) + 200.0845 e^{-t/\tau}$

$\tau_a = \frac{L}{R} = \frac{L_a + L_L}{R_{add} + R_a + R_L} = \frac{(0.3 + 1.7) \times 10^{-3}}{0.4 + 0.1 + 1.1}$

$= \frac{2 \times 10^{-3}}{1.6} = 1.25 \times 10^{-3}\,s = \frac{1}{800}$

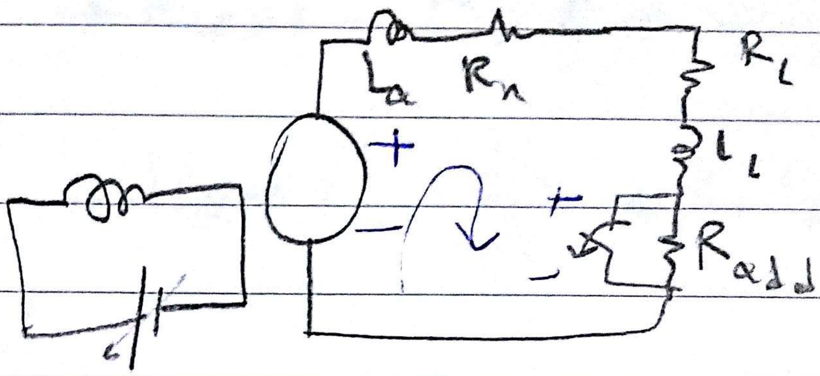
$i_a(t) = 150.06375(1 - e^{-800t}) + 200.0845 e^{-800t}$

$= 150.06375 + 50.02075 e^{-800t}$

الجهد المسلط على المقاومة تم خفضه بمقدار 80

$I_{a_0} = 200.0845 A$

$R_{add} = 0.9 \Omega$



$\Delta V = -80.0338 V$

الجهد على المقاومة يتغير بشكل فجائي (لحظي)

$$\Delta i_a(t) = \frac{\Delta V}{R} \left(1 - e^{-t/\tau}\right)$$

final

لكن التيار في الدائرة يتغير ويتزايد exponential

$$= \frac{-80.0338}{1.6} \left(1 - e^{-800t}\right)$$

$$= -50.02 \left(1 - e^{-800t}\right)$$

$$i_a(t) = \Delta i_a(t) + I_{a_0}$$

$$= 200.0845 - 50.02 \left(1 - e^{-800t}\right)$$

$$= 150.0637 + 50.02 e^{-800t}$$